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HOSPITAL DEMAND FOR NURSES

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ABSTRACT

In the mid-1980s, hospitals increased employment of registered nuraes while substantially reducing staffing of licensed practical nurses and ancillary nursing personnel. Greater hospital demand for registered nurses resulted in a nursing "shortage". Our cross-sectional estimates indicate that nurae wage rates, hospital outputs, and market competition affect hospital demand for nurses. However, changes in wages and hospital outputs do not account for higher hospital demand for registered nurses in the 1980s. Substitution of registered nurses for the lower-skilled nursing categories in order to achieve a more coat-efficient mix of nursing personnel was more important in increasing demand.

HOSPITAL DEMAND FOR NURSES

1.0 INTRODUCTION AND BACKGROUND

Major changes have occurred in hospital markets in the 1980s. In an attempt to contain spiraling Medicare expenditures, the Federal government adopted the Prospective Payment System in 1983 to reimburse hospitals for inpatient treatment of Medicare beneficiaries. In place of the previous retrospective cost-based reimbursement, hospitals are now paid prospectively-determined lump sum amounts based on patient diagnosis. In addition, "peer review organizations" were adopted to reduce medically unjustified inpatient admissions. Private health insurers have also attempted to reduce costs and utilization through increased use of managed care, bargaining on price with medical providers, and utilization review activities.

The apparent effect of these efforts has been fewer, but more severely ill, inpatient admissions, lower length of stay, and increased outpatient activity (Table 1).[1] From 1980 to 1987, short-term general hospital admissions fell by 13 percent and length of stay by 5 percent, but outpatient visit3 rose 20 percent. Medicare casemix, a measure of the expected resource intensity of Medicare inpatients, increased 13 percent from 1981-87.

The rapid changes in hospital outputs might be expected to have important implications for hospital derived demand for inputs. Nursing personnel are the most numerous category of hospital employees, accounting for nearly two-fifths of hospital employment. The three major types of nursing personnel had very different experience3 during the 1980s (Table 1). From 1980 to 1987, hospital employment of registered nurses (RNs) rose from 600,000 to 737,000, an increase of 23 percent. Conversely, employment of the less-highly-trained licensed practical nurses (LPNs), and ancillary nursing personnel (ANP) fell by 25 percent and 10 percent, respectively. Thus, there has been a substantial upgrading of the skill mix of hospital nursing personnel in the 1980s.

Table 1 about here

Hospitals' desire to employ RNs increased so rapidly during the 1980s that reports of a "nursing shortage" developed. Most analysts of this situation believe that the "shortage" was due primarily to increased hospital demand for RNs, rather than supply factors, because actual employment of RNs has increased ao rapidly (Roberts et al., 1989; U.S. Department of Health and Human Services, 1988).

One of the most important trends thought to increase demand for RNs as compared to leas skilled nursing personnel is the greater illness severity of inpatients. Concern over the "shortage" of RNs has prompted proposals for an increase in Medicare hospital reimbursement to raise nurae salaries, and for expanded federal subsidies to nursing education (U.S. Department of Health and Human Services, 1988).

In spite of the policy importance of understanding hospital demand for nurses, little econometric evidence has been presented on the issue. Using 1969 data, Ehrenberg (1974) found some evidence that hospitala substitute LPNs for RNs in response to their relative wages, but while the own-price effects were negative, the cross-price effects were usually insignificant. Moreover, although employment in private nonprofit and for-profit hospitals did respond to relative wages, state and local government hospital employment was insensitive to the wages of different categories of nurses. Sloan and Steinwald (1980) estimate equations for RNs per bed and LPNs per bed using pooled 1969 to 1975 data. They found that moat of the own price effects were negative and the cross-price effects were positive. Robinson (1988) estimated reduced-form equations for hoapital nurse employment and skill mix. He found that hospitals in more competitive markets employ more nurses and a higher skill mix of nursing personnel. None of these studies focuses on the effects of hospital output on demand for nurses.

In this paper, we present cross-section estimates of hospital demand for registered nurses and nursing personnel mix using *primarily* 1982 data. Our estimates provide basic evidence on the factors influencing hospital demand for nurses, in particular hospital outputs, nurse wage rates, the substitutability *of* LPNs and ANP for RNs, and market competition. Moreover, the estimates can be used to help understand the dramatic changes in nursing personnel mix that occurred in the 1980s. Our estimates imply that the changes in hospital outputs and nurse *wages* since 1982 do not account for the increased demand *for* RNs. *A more* important factor seems to be that hospitals improved the efficiency of their nursing personnel mix in the mid-1980s. However, changes in outputs, wages, or nursing mix do not fully account for the increases in RN staffing. We discuss some of the other factors that may be involved in *our* concluding comments.

2.0 SPECIFICATION OF DEMAND EQUATIONS

To specify the demand equations for nurses, we rely on the standard economic theory of the demand for labor of a cost-minimizing firm. Minimizing the cost of producing output subject to a production technology yields the conditional factor demands as functions *of* input prices and output (Varian, 1978). *We* assume that hospitals first determine (or forecast) output, then develop their input demands. In this recursive system, output can be treated as exogenous in the demand equations.

Assuming cost-minimization may be unwarranted because hospitals *were* generally reimbursed for their incurred costs during our sample period (1982), giving them little incentive to provide services efficiently.' Nevertheless, the standard theory of the derived demand for inputs provides a useful basis for specification of demand relationships. Because of the tenuous nature of the cost-minimization hypothesis, however, we do not use the demand estimates to infer the substitution possibilities *of* the nursing production function.

focus on the more basic question of whether our estimates are

with cost-minimizing behavior by hospitals. Most importantly, do hospitals substitute against an input as its price rises relative to substitutes?

We assume a three-factor production function for nursing services, with inputs of RN time, LPN time, and ANP time. Other personnel (e.g., unit secretaries, medical technologists, and physicians) may substitute to some extent for nursing personnel, and capital expenditures on building design and monitoring equipment can reduce nurse staffing requirements (U.S. Department of Health and Human Services, 1988). However, we believe that the three skill levels of nursing personnel capture the most important substitution possibilities, so that other inputs can be ignored without significant bias.

A specific functional form for the production technology must be assumed to derive estimable demand relationships. In recent econometric research, 'flexible' functional forms that can provide a second-order approximation to an arbitrary production technology have gained favor. However, although they furnish a more flexible local approximation, these forms do not necessarily have better global approximation properties than simpler functional forms (Chambers, 1988). The flexible forms are most useful in deriving accurate estimates of substitution possibilities when cost minimization can be reasonably assumed. They are not necessarily better suited to our purpose of testing the basic consistency of hospital behavior with cost minimization. Moreover, the conditional factor demands associated with several popular flexible forms, including the translog, are nonlinear in the parameters, and thus are difficult to estimate and interpret.[3]

A convenient specification of the demand for registered nurses can be derived from the Cobb-Douglas production structure (Varian, 1978):

$$\ln(RN) = a_0 + a_1*\ln(W_{LPN}/W_{RN}) + a_2*\ln(W_{ANP}/W_{RN}) + a_3*\ln(Y), \quad (1)$$

where W_{LPN} is the wage rate of LPNs, W_{RN} is the RN wage rate, W_{ANP} is the ANP wage rate, and Y is hospital output. The coefficients a_1 and a_2 allow us to test whether RN demand is sensitive to relative wages, and a9 indicates the responsiveness of demand to hospital output.

Intuitively appealing demand equations for **hospitals'** mix of nursing personnel can be derived from the nonhomothetic constant elasticity of substitution technology (Sato, 1977):

$$\ln(RN/LPN) = b_0 + b_1*\ln(W_{LPN}/W_{RN}) + b_2*\ln(Y) \tag{2}$$

$$\ln(RN/ANP) = c_0 + c_1*\ln(W_{ANP}/W_{RN}) \text{ t } c_2*\ln(Y). \tag{3}$$

The coefficients b_1 and cl test the sensitivity of nursing staffing mix to relative wages (if hospitals minimize **costs,** they are the elasticity of substitution between **RNs** and LPN, and **RNs** and **ANP).** The coefficients b2 and c_2 indicate the effect of output on nursing mix. If mix is invariant to the scale of output (b2=c2=0), the provision *of* nursing services is characterized by a homothetic technology.

The demand relationships **(1)-(3)** explain nurse demand by relative wages and output. In addition to these equations, we estimate a relationship that explains **RN** employment by LPN and *ANP* **staffing** and output. This equation is derived by solving the Cobb-Douglas production function $Y = A(RN)^a(LPN)^b(ANP)^c$ for RN:

$$\ln(RN) = C - (b/a)\ln(LPN) - (c/a)\ln(ANP) + (1/a)\ln(Y), \tag{4}$$

where A and C are constants. Equations analogoua to (4) have been used to estimate labor **"requirements" as a function** *of* the capital stock and output (Intriligator, 1978, pp. **286-87).** Thus, we *refer to* equation (4) **as** the RN requirements equation. Because equation (4) is just a restatement of the production function, eatimating it aaaumea only technical efficiency in hospital production. The estimates can be used to teat the stronger assumption inherent in the **demand** equations that hospitals are using a coat-minimizing mix of nursing personnel.

The coefficients of LPN and ANP in equation (4) provide direct estimates of **substitution poaaibilitiea in nursing services. Holding output constant, how much do hospitals that uac more LPNs and ANP reduce their RN staffing,** if at all? Under the Cobb-Douglas assumption, the marginal rats of technical substitution (MRTS) between RNs and LPNs is (b/a) (RN/LPN) and between RNs and ANP is (c/a)(RN/ANP) (Varian, 1978). Hence, the coefficients of LPN and ANP in equation (4), together with the average ratios of RNs to LPN3 and RNs to ANP, can be used to calculate the average MRTS among nursing personnel in a sample of hospitals. If these hospital3 are employing a cost-minimizing mix of nursing personnel, the MRTSs should equal the corresponding wage ratios.

Since the late 19303, the market for registered nurses has been characterized by recurrent "shortages" (Yett, 1975). One probable reason is that the hospital labor force has been expanding more rapidly than employment in other sectors of the economy. Hospitals have had to continually raise wages to attract more workers. If wages are raised with a lag, dynamic shortage3 of the type noted by Arrow and Capron (1959) in the market for engineers can arise. Employment is constrained by supply until the wage rises to its equilibrium level. Persistent reports of shortages have also led Yett (1975) and other3 to note that if hospitals are monopsonists in the market for RNs, "equilibrium" shortages can exist. Hospitals would like to hire more nurses if they could do so at their current wage. Because they are facing an upward-sloping supply curve for nurses, however, they would have to raise their wage to attract more nurse labor, 90 they do not, in fact, increase employment. Hospitals might report the difference between their monopsonistic employment and their desired employment at the monopsony wage as a persistent shortage of nurses.

In either case--a dynamic shortage with "sticky" wages or monopsony--observed nurse wage/employment pairs identify points on the supply, not the demand, curve. However, if hospitals' reported shortages (i.e., budgeted vacancies) are added to actual employment, the (input-price-taking) hospital demand curve for nurses is identified even under condition3 of dynamic shortage or monopsony.[4] This is the approach we take to identifying the hospital demand relationships (1)-(3) in our empirical work. Because the RN requirements equation (4) is a production, not a demand relationship, we do not add vacancies to employment for that equation. We do include contract (i.e., temporary) nurses in addition to employees in the requirements equation.

A final issue in the specification of equations, (1)-(4) is the measurement of hospital output. Hospitals are multiproduct firms. Simply using discharges or inpatient days as the hospital output measure does not account for the wide variety of cases hospitals treat, nor the increasingly important outpatient activity of hospitals. Ideally, the number of cases a hospital treats in each diagnostic category would be included among the output measures, but the large number of different diagnoses (Medicare uses 470 to determine its payment rates) makes this approach impractical. A reasonable compromise is a "hedonic" approach that includes a few descriptors of the type of hospital output in addition to basic measures of scale such as discharges and outpatient visits. The hedonic approach has also gained favor in measuring output in other industries (see Spady and Friedlatnder, 1978, for an early example).

The most important hedonic descriptors of output (discharges) for hospitals are diagnostic mix of cases treated, or "casemix", and average length of stay. A casemix index collapses a hospital's diagnostic mix of cases into a scalar measure by weighting proportions of diagnoses treated by expected resource intensity by diagnosis, and summing. Average length of stay measures hospital production of "hotel-type" services; more days in the hospital for the average patient should raise demand for nursing services, other things equal.

3.0 DATA

To estimate hospital demand for nurses, wage rates of nursing personnel are necessary. To our knowledge, no hospital-specific wage data for RNs, LPNs, and ANP are available for a large, nationally-representative sample of hospitals. Instead, we use the median hourly earnings of RNs, LPNs, and nursing aides, orderlies, and attendants from a special tabulation of the 1980 Census of Population and Housing purchased by the Health Care Financing

Administration for regulatory purposes. These data are highly accurate because they are derived from the full 20 percent Of the population sample that was asked earnings questions in the 1980 Census, not the 1 or 5 percent public use files. Occupation, earnings, and hours worked are self-reported to the Census and refer to calendar year 1979. Earnings by occupation were tabulated for each of the 317 Metropolitan Statistical Areas (MSAs) and the 49 aggregations of nonmetropolitan counties in a state (all New Jersey counties are metropolitan). Thus, there are 366 distinct observations of nurse wage rates. The hourly earnings of LPNs vary from 58 to 90 percent of RN earnings across areas, while the earnings of ANP range from 40 to 68 percent of RN earnings. Because the Census hourly earnings data are defined for market areas, and include nonhospital as well as hospital nurses, they are better measures than hospital-specific wage data of the exogenous relative wage3 faced by hospitals in their market area.

Diagnostic mix ("casemix") of patients treated is an important descriptor of hospital output, which we expect to be closely related to nursing intensity. Unfortunately, no caaemix data are available for all patients treated for all hospitals. However, we obtained a 1983 casemix index for Medicare patients. The index is defined as the sum of the proportions of 470 different diagnoses treated in each hospital weighted by the national average coat for that type of case, standardized by the national average cost for all cases. Medicare patients account for about 30 percent of total short-term general hospital admissions and Medicare casemix is highly correlated with casemix for all patients. We also obtained each hospital's ratio of interns and residents to beds for 1983, which is a continuous measure of a hospital's teaching role.

The source for all other variables is the annual American Hospital Association (AHA) Survey of Hospitals. We chose to use 1982 AHA data in part to be temporally consistent with our 1979 wage data and 1983 casemix data. Moreover, 1982 is prior to the significant changes in Medicare hospital reimbursement beginning in 1983 that make interpretation of cross-sectional estimates as long-run equilibrium quantities problematic for the succeeding years. In 1982, hospitals had low average vacancy rates of 3.7 percent for RNs, 2.0 percent for LPNs, and 1.2 percent for ANP, supporting the equilibrium interpretation (i.e., hospitala were generally able to hire as many RNs, LPNs, and ANP as they wished). An additional advantage of using data prior to 1985 is that budgeted vacancies and contract personnel were collected on the AHA annual survey only until 1984. Some random measurement error is involved in using 1979 wages and 1983 casemix with 1982 employment, which may impart a downward bias to the wage and casemix coefficients. However, relative wages and casemix were unlikely to be changing rapidly over the relevant period. Moreover, proportional change in relative wages (casemix) in all areas (hospitals) is absorbed into the constant term of our logarithmic regressions without biasing the wage (casemix) coefficient.

Hospitals report full-time and part-time RN, LPN, and ANP employees to the AHA. These were converted into full-time equivalents (FTEs) by adding one-half of part-time employment to full-time employment. Only total vacancies and contract personnel are reported: we assumed that the ratio of FTEs to total positions was the same among vacancies and contract personnel as among each hospital's employees. Our dependent variables were then constructed by adding FTE budgeted vacancies (for the demand equations) or contract personnel (for the requirements equation) to FTE employment. As additional descriptors of hospital outputs, we include intensive care days as a proportion of total inpatient days, inpatient and ambulatory surgical operations per discharge and outpatient visit, respectively, and births per discharge.[5] The hospital occupancy rate controls for capacity utilization. Hospital ownership (private nonprofit, government, and for-profit) and rural-urban location measure different hospital objectives, efficiency, treatment intensities, and types of patients. A herfindahl index of hospital beds in a metropolitan area or in a rural county captures the extent of competition in a hospital's market area.

The 1982 AHA survey contains 5687 nonfederal short-term general hospitals. Eliminating hospitals with imputed or missing data on any of our variables reduces the sample to 1612. In addition, hospitals with zero LPNs, ANP, or outpatient visits are at corner solutions not allowed by our specifications, so they are also deleted. Of the 1612 hospitals, 11.7 percent reported no ANP, 1.3 percent no LPNs, and 0.5 percent no outpatient visits (all hospitals employed RNs). The final sample site is 1402. Although this is only one-quarter of the universe of nonfederal short-term general hospitals, our sample is representative of the universe with respect to hospital bedsize (175 on average for our sample versus 168 for the universe),[6] occupancy (68% versus 67%), proportion of rural hospitals (48% for both), and proportion of government-owned hospitals (29% versus 30%). However, proprietary hospitals are somewhat underrepresented in our sample (9% versus 13% in the universe). Means and standard deviations for all variables used in the regressions are shown in Table 2' for the sample of 1402 hospitals.

Table 2 about here

4.0 RESULTS

Table 3 shows ordinary least squares estimates of the three nurse demand equations and the RN requirements equation. We will discuss the demand equations first. Hospital demand for RNs is influenced by the relative wages of nursing personnel: both relative wage coefficients are significant at the 5 percent level in the Cobb-Douglas RN demand equation. The magnitude of the wage effects is rather small, however. Demand for RNs is estimated to decrease by 2.3 percent for every 10 percent increase in the RN wage relative to the LPN wage and by 6 percent for every 10 percent increase in the RN to ANP relative wage. The greater responsiveness of RN demand to the relative wage of ANP is surprising since LPNs should be closer substitutes for RNs than ANP.

Demand for the mix of RNs relative to other nursing personnel is much more responsive to relative wages than absolute RN demand. A 10 percent increase in the RN to LPN wage reduces RN demand relative to LPN demand by

18.4 percent. Similarly, a 10 percent increase in the RN to ANP wage ratio reduces RN relative to ANP demand by 13.0 percent. Taken together, the estimates of absolute and relative RN demand imply that LPN and ANP demand is much more responsive to relative wages than is RN demand. The wage coefficients provide evidence that, even in the era of cost reimbursement, hospitals substituted against inputs whose relative price was higher. At least in this minimal sense, therefore, hospital behavior was consistent with cost minimization.

The coefficient of discharges is significantly less than one in the RN demand equation, implying increasing returns to scale in the production of nursing services. Ten percent more discharges increases demand for RNs by only 8.6 percent. Discharges has a negative coefficient in the two *nursing mix* equations, although it is significant only in the RN/ANP regression. Hospitals tend to use a higher proportion of RNs in their nursing personnel mix at lower scales of operation. This could be because LPNs and ANP cannot substitute for RNs in all nursing activities, or because of legal requirements to maintain certain minimal levels of RN staffing. The magnitude of the nonhomotheticity in the nursing production function is small, although the discharge coefficients in the mix equations could be biased toward zero by the exclusion from our sample of hospitals that employ no LPNs or ANP.

Table 3 about here

A more costly diagnostic mix of cases increases RN demand, both absolutely and relative to less-highly-trained nursing personnel. A 10 percent increase in the expected cost of Medicare cases (i.e., in the Medicare casemix index) raises RN demand by 6.9 percent and demand for RNs relative to both LPNs and ANP by-about 8 percent, all else equal.

A longer average length of atay raises RN demand, but not proportionally. A hospital demands 5.8 percent more RNs when its length of stay is 10 percent longer, implying that the later, recuperative days of a stay are less RN intensive. In these later, less intensive days of a stay, it might be expected that other nursing personnel could more easily substitute for **RNs.** Indeed, a 10 percent longer length of **stay reduces** demand for **RNs** relative to ANP by **a** statistically significant 2.0 **percent. LPNs,** however, are less substitutable ***for* RNs** than ANP as length of stay increases: the length of stay coefficient, while negative, **is** small and statistically insignificant in the **RN/LPN** mix regression.

More outpatient visits raise **RN** demand, but its smell coefficient indicates strongly increasing returns to scale in the provision ***of*** outpatient nursing services. Ten percent more outpatient visits, **ceteris paribus,** raises demand *for* **RNs** by less than 1 percent. Hospitals with more outpatient visits also demand a **more** RN-rich nursing mix. This is presumably because outpatient visits include **emergency room and critical care** visits, which require the more highly-trained **RNs.** The magnitude of the effect on ***nursing mix*** is again small..

All else equal, hospitals with lower occupancy rates demand more **RNs,** both absolutely and relative to other nursing personnel. This ***may*** be because lower-occupancy hospitals (e.g., small or isolated rural hospitals) *are* maintaining a greater reserve margin of capacity, including **RNs,** but not **LPNs *or* ANP,** to deal with random fluctuations in demand (Joskow, 1980). ***Or*** hospitals may base their RN staffing, but not LPN or ANP staffing, in part on hospital size. Because of higher turnover or recruitment costs, they may be less willing to reduce **RN** staffing in response to possibly short-term reductions in occupancy.

Intensive care of patients requires both **more RNs** and more *of* these highly-trained nurses relative to the less-skilled **LPNs and** ANP. A one percentage point increase in intensive care days as a proportion of total inpatient days raises RN demand by 2 percent, and by 1.7 percent relative to LPN demand and 3.3 percent relative to AND demand. The lower-skilled **ANP** *are* thus least associated with intensive care of patients.

As the number of surgeries per discharge or outpatient visit rises, demand for **RNs** increases absolutely **and** relative to other nursing personnel. **RNs are** better trained to provide services to these *more* difficult cases than **LPNs or** ANP. ANP **seem to be especially <u>not</u> associated with inpatient surgical** operations, and LPNs not associated with outpatient surgical operations. A higher proportion of maternity cases among discharges also increases demand for RNs absolutely and in the mix of nursing personnel, although the mix effects are not statistically significant at the 5 percent level. A one percentage point increase in the proportion of births is estimated to increase RN demand by .8 percent.

Hospital characteristics affect the demand for nurses holding constant wages and the number and types of cases. A greater teaching role (measured by interns/residents per bed) increases a hospital's demand for RNs, probably due to a more intensive, "high technology" style of care and/or a more severe mix of patients not measured by our casemix variables. Teaching role also tends to increase the demand for RNs relative to other nursing personnel, but these "mix" effects are not statistically significant. Government hospitals demand fewer RNs, both absolutely (7 percent fewer) and relative to other nursing personnel (10 percent fewer relative to LPNs and 28 percent relative to ANP), than private nonprofit hospitals (the omitted ownership category). Government hospitals seem to substitute LPNs and especially ANP for RNs. Proprietary hospitals do not differ significantly from private nonprofits in their demand for RNs absolutely or relative to LPNs. In contrast to government hospitals' extensive use of ANP, proprietary hospitals use many fewer ANP than other types of hospitals (23 percent fewer ANP relative to RNs than private nonprofits).

Hospitals located in nonmetropolitan (rural) counties demand 11 percent fewer RNs, 24 percent fewer RNs relative to LPNs, and 14 percent fewer RNs relative to ANP than urban hospitals, holding other regressors constant. Rural hospitals seem to substitute ANP and especially LPNs for RNs. Their less intensive style of care than urban hospitals (Cromwell et al., 1987), and, possibly, less severe cases not measured by our casemix variables probably account for their lower demand for RNs.

Greater competition in a hospital's market area increases its demand for RNs. Because we control for a lower monopsony demand for nurses by including budgeted vacancies in the dependent variable, we interpret the herfindahl coefficient as the effect of **nonprice** quality competition in the output *market.* About 12 percent more **RNs** are demanded, **ceteris paribus,** in highly competitive *markets* (a herfindahl approaching *zero)* *than* in monopolistic markets (a *herfindahl* of one). Competitive pressures also force hospitals to upgrade their skill mix of nursing personnel. The RN to LPN ratio is as much as **50** percent higher in highly competitive than monopolistic markets and the **RN** to ANP ratio is about 11 percent higher (the latter effect is not statistically significant). It appears that in competitive markets, hospitals substitute **RNs** for the lower-skilled ANP and especially **LPNs** to attract patients and physicians..

We now turn to the Cobb-Douglas RN requirements equation. Full-time equivalent **LPNs** and ANP (including *contract* personnel) are entered as explanatory variables in this regression instead of relative wages. The other regressors *are* the same as in the three demand equations. Although the theoretical interpretation of the coefficients *of* the output variables is somewhat different than in the Cobb-Douglas demand equation,[7] the estimated coefficients are *very* similar. Therefore, we focus on the LPN and ANP coefficients. These coefficients are both negative and statistically significant: hospitals that employ more **LPNs** or more AND employ fewer **RNs,** holding hospital outputs constant. The negative LPN and **ANP** coefficients are *direct* evidence of technical substitution possibilities in the production of nursing services. Moreover, as expected, **LPNs** appear to be more substitutable for **RNs** than **ANP.** The estimated elasticities **are** small, however. Ten percent more **LPNs** reduce employment of **RNs** by only 1.2 percent and 10 percent more ANP reduce RN employment by only about **.5** percent.

As explained above, the LPN and **ANP** coefficients can be used to calculate the marginal rate *of* technical substitution **(MRTS)** between **RNs** and **LPNs,** and **RNs** and ANP. The estimated **MRTSs** are accurate only if the Cobb-Douglas form is a valid representation of the technology of nursing services. In particular, the estimated **MRTS** is sensitive to the Cobb-Douglas assumption that one input (e.g., **LPNs)** is increasing difficult to substitute *for* **another (e.g., RNs) as less** *of* **the second input is** utilized **(i.e.,** the assumption of a unitary elasticity of substitution). Under the Cobb-Douglas assumption, the estimated average MRTS of LPNs for RNs in our sample of hospitals is (.124)(3.50) = .43, where .124 is the (absolute value of) the coefficient of LPN in the RN requirements *regression,* and 3.50 is the *average* ratio of RNs to LPN8 (including contract personnel) among sample (N-1402) hospitals. Similarly, the average MRTS of *ANP for* RNs in sample hospitals is (.045)(2.85) = .13. Thus, at the *average* relativa levels of employment *of* RNs and LPNs or ANP in this sample *of* hospitals, one LPN could substitute for .43 RNs, and one ANP could substitute for .13 RNs, at the margin.

Hospitals *are* employing a cost-minimizing mix *of nursing* personnel only if the MRTS between different types of *nursing* personnel equals the ratio of their wages. The average LPN/RN wage ratio among sample hospitals was .72 (Table 2), considerably greater than the estimated average MRTS of .43. The average ANP/RN wage ratio was .52, also much larger than the estimated MRTS of .13.[8] Thus, in 1982, hospitals appear to have inefficiently underutilized RNs relative to LPNs and ANP. Among ownership classes, government hospitals appear to have been especially egregious in their underuse of RNs relative to other nursing personnel, while proprietary hospitals were *more* efficient in their mix of RNs and ANP than other hospitals (these statements are based on the ownership coefficients in the RN/LPN and RN/ANP mix equations, which control for relative wages).

An alternative interpretation of the inequalities between the MRTSs and the wage ratios is that hospitals had considerable monopsony power in the RN labor *market,* but not in the LPN or ANP labor markets. In this case, the marginal cost of RNs to the hospital could be much higher than their wage, but the marginal cost of LPNs or ANP would be nearly equal to their wage. A profit-maximizing monopsonist sets the MRTS equal to the ratio of marginal factor costs rather than the wage ratio. Thus, a LPN/RN or ANP/RN wage ratio exceeding the corresponding MRTS could be *consistent* with monopsonistic hospital behavior. However, it seems unlikely that, on average, hospitals had enough monopsony power in the RN market, but not in the LPN and ANP markets, to account for the observed inequalities.

5.0 IMPLICATIONS

The regression results reported in the previous section can be used to help understand the major changes in hospital nurse staffing that have taken place in the mid-1980s (Table 1). Table 4 presents changes in hospital output and wages from 1982 to 1987, and the estimated effects on RN demand, computed using the coefficients of the Cobb-Douglas RN demand equation (Table 3). (There was virtually no change in interns/residents per bed, ownership status, and the herfindahl index.) Where possible, changes were calculated for the sample of 1402 hospitals used for the 1982 regressions. We were able to match 1987 data for 1350, or 96 percent, of the 1402 hospitals using the 1987 American Hospital Association Survey tape. Median changes are used rather than average changes because of extreme outliers in the percent changes of some variables. The 1982-87 change in several variables (e.g., wages, casemix) could not be calculated for this sample of hospitals. For these variables, more approximate sources (generally national averages) were used.

Because of the uncertainty in the regression coefficient estimates and some of the 1982-87 changes, the estimated effects on RN demand are only approximations. Nevertheless, certain general conclusions can be drawn from Table 4. First, changes in relative nurse wages did not contribute to the median hospital RN staffing increase of 10.9 percent. Over this period, RNs were becoming more expensive relative to other nursing personnel, which is estimated to have reduced RN demand by about 7 percent. Second, changes in hospital outputs also do not appear to account for the greater employment of RNS. Increases in demand for RNs due to a more severe casemix and more outpatient visits were offset by decreased demand from fewer discharges and shorter length of stay. On net, output changes are estimated to have reduced RN demand by about 6 percent.

Table 4 about here

Direct substitution of RNs for LPNs and ANP seems to have been more important in explaining RN staffing increases. Using the coefficients of the Cobb-Douglas RN requirements equation (Table 3), we estimate that about 5 percent more RNs were necessary to substitute for the 28 and 35 percent median reductions in the LPN and ANP staff8 of our sample of hospitals. This represents almost half of the 10.9 percent median RN staffing increase.

By substituting RNs for LPN8 and ANP, hospitals moved to a more efficient mix of nursing personnel. As shown above, in 1982 hospitals underused RNs *relative to* LPNs and ANP. Between 1982 and 1987, the hospitals in our sample increased their average RN/LPN ratio from 3.50 to 5.79, and their RN/ANP ratio from 2.85 to 4.94.[9] Using the coefficients from the RN requirements regression (Table 3), the implied MRTSs in 1987 are (.124)(5.79) = .72 of LPNs for RNs, and (.045) (4.94) = .22 of ANP for RNs. The estimated 1987 average ratio of the LPN to RN wage is .66 and of the ANP to RN wage is .48.[10] Thus, by 1987, hospitals employed a roughly cost-minimizing mix of LPNs and RNs, and had moved toward a more efficient ANP and RN mix. Our estimates indicate, however, that hospitals still overemployed ANP relative to RNs in 1987.[11]

6.0 CONCLUDING REMARKS

Hospitals reduced costs in 1982 to the extent of substituting against nursing personnel whose relative wage was higher in their labor market area. However, they did not, on average, employ a cost-minimizing mix of nursing personnel. Since that time, the implementation of prospective payment by Medicare and *greater* price sensitivity on the part of private third-party insurers has given hospitals greater incentives for efficiency. One response of hospitals seems to have been a movement toward a more efficient mix of nursing personnel. RNs are more expensive than LPNs or ANP, but their relative marginal product is such that they were underutilized by hospitals in the early 1980s. By increasing their employment of RNs, and reducing their

LPN and ANP staffing, hospitals had achieved a less costly mix of nursing personnel by 1987.

Nevertheless, by our estimates, much of the increased hospital RN staffing in the 1980s is not explained by changes in hospital outputs, nurse wages, or nursing personnel mix.[12] Revenue margins and competition may explain at least some of the rest. Hospital revenue margins (profits) were at record highs in the early years of the Medicare Prospective Payment System (mid-1980s) (Prospective Payment Assessment Commission, 1988). Hospitals, which as predominantly nonprofit institutions must reinvest surplus funds, had excess revenues that could be spent on increasing their input intensity or quality of care. Hiring RNs made particular sense because of increased competition for physicians and patients. RN staffing--both number of RNs and a more RN-rich mix of nursing personnel--is often viewed as an indicator of the quality of nursing care in a hospital. Indeed, our empirical estimates show that greater market competition leads to a higher demand for RNs and for RNs relative to LPNs and ANP. The implementation of volume-based reimbursement systems such as the Medicare Prospective Payment System meant that, to a much greater extent than previously, hospitals had to attract patients to generate revenues. Increasing RN staffing may have been a good means of doing so.

As this is being written in late 1989, the nursing "shortage" seems to be easing. RN wage rates have risen dramatically in real terms and relative to LPNs and ANP in the late 1980s (U.S. Department of Labor, 1987, 1989). As our estimates predict, this appears to have begun reducing hospital demand for RNs. There is evidence that in some areas RN vacancy rates are falling and that hospitals are eliminating RN positions.[13] Thus, the RN *shortage", at least in it8 acute phase, appears to be a temporary phenomenon that will be eliminated as wage rates adjust to their equilibrium values.

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FOOTNOTES

[1]Other factors have also contributed to the change3 in hospital output3 during the 1980s, including technological advances that have allowed outpatient surgery to substitute for some inpatient surgery.

[2]Previous empirical work has questioned whether hospital3 minimize costs in their choice of nursing input3 (Ehrenberg, 1974).

[3]Equations explaining the share of each factor input in costs take a simple form under the translog specification and are often estimated jointly with a cost function (e.g., Spady and Friedlaender, 1978). However, the factor shares are explained only by input price3 independent of output. Relating factor shares to input prices is of limited interest to us.

[4]A monopsonist does not have a demand curve in the usual sense of a relationship between an exogenous wage and desired employment. However, by adding vacancies, we identify the demand relationship that would exist if the hospital took wage3 as exogenous, even if it is in fact a monopsonist. Thus, we interpret our result3 as the derived demand curve of a wage-taking hospital. Our results do not reveal how monopsonistic employment would respond to change3 in supply and demand factors. Empirical results are mixed, but the best evidence indicate3 that hospitals have little monopsony power (Adamache and Sloan, 1982; Sloan, 1978). Thus, we believe that the demand curve of a wage-taking hospital is the most relevant relationship to estimate.

[5]Even though some discharges or visits may involve multiple surgeries or births, these variable3 can be approximately interpreted as proportions.

FOOTNOTES

(continued)

[6]Our sample of 1402 hospitals has the following bedsize distribution compared to all nonfederal short-term general hospitals: less than 100 beds: 44% versus 49%: 100 to 300 beds: 30% versus 34%: more than 300 beds: 18% versus 17%.

[7]In the demand equation (1), the coefficient on output measures returns to scale, while in the requirements equation (4), it is the reciprocal of the elasticity of output with respect to RNs.

[8]The LPN/RN and ANP/RN wage ratios are based on 1979 Census data. Since the early 1980s, RN wages have risen relative to those of LPNs and ANP. If this trend also held from 1979 to 1982, the 1979 values would slightly overstate the 1982 values.

[9]Unlike the 1982 ratios, the 1987 figures do not include contract personnel because the AHA Survey of Hospitals did not collect this information in 1987. This may create a slight downward bias in the 1987 ratios relative to the 1982 ratios because more *contract* RNs are used than other types of nursing personnel.

[10]The wage ratios are estimated from the 1982 values (based on 1979 data) of .72 and .52 reduced by the estimated *percentage* changes from Table 4.

[11]The hospital RN vacancy rate rose *from* 3.7 percent in 1982 to 11.3 percent in 1987 (U.S. Department of Health and Human Services, 1988, Vol. I, p. 3), while it likely that the ANP vacancy rate was very low in 1987. Thus, hospitals*

FOOTNOTES

(continued)

desired RN/ANP ratio was higher in 1987 than the actual ratio, implying less inefficiency in demand for nursing mix than comparing the actual MRTS to the wage ratio indicates. By the same token, the desired RN/LPN ratio was higher than the actual ratio, which was approximately efficient according to our estimates. This perhaps indicates that demand for LPNs was inefficiently low by 1987.

[12]Because RNs may substitute for hospital personnel other than LPNs or ANP, our estimates of the proportion of the increase in RN staffing attributable to personnel substitution may be too low. Another factor not taken into account in our estimates is the diffusion of sophisticated new technologies and treatment regimes that are RN intensive (Roberts et al., 1989). However, it seems unlikely that technology diffusion was rapid enough over such a short time period to account for much of the nurse staffing changes in the mid-1980s.

[13]Boston Globe, October 21, 1989, 'Nursing shortage eases as salaries rise'.

TABLE 1

CHANGES IN HOSPITAL OUTPUTS AND NURSE STAFFING DURING THE 1980s

Hospital Outputs	1980	1982	1984	1986	1987	Percent Change 1980 - 1987
Admissions[a] (millions)	36.2	36.4	35.2	32.4	31.6	-12.6%
Length of Stay[a] (days)	7.6	7.6	7.3	7.1	7.2	-5.3
Outpatient visits[a] (millions)	206.8	210.4[e]	216.5	234.3	247.7	19.8
Medicare Casemix Index[b]	1.000[c]	--	1.059	1.114	1.134	13.4[d]
Nurse Staffing						
RNs (100,000)[b]	6.00	6.54	6.70	7.08	7.37	22.7
LPNs (100,000)[b]	2.22	2.35	2.00	1.69	1.68	-24.5
ANP (100,000)[b]	2.54	2.82	2.51	2.20	2.29	-9.8
RNs as a Percent of Total Nursing Personnel[b]	55.8%	55.9%	59.8%	64.5%	65.0%	16.5

Note: RN = registered nurses, LPN = licensed practical nurses, ANP = ancillary nursing personnel.

[a]Total nonfederal short-term general and other special hospitals, from American Hospital Association, 1988, Table 1.

[b]For hospitals eligible for Medicare's Prospective Payment System. Casemix data are from Prospective Payment Assessment Commission, 1989. Nurse staffing was calculated from the American Hospital Association Annual Survey of Hospitals computer tapes.

[c]1981 value.

[d]Percent change 1981-87.

"Interpolated from the 1981 and 1983 figures. A one-time change in the American Hospital Association Survey make8 1982 outpatient visits incomparable with other years.

TABLE 2

MEANS AND STANDARD DCVIATIONS OF REGRESSION VARIABLES,

Variable	Mean	Standard Deviation	Source
RN[a]	120.480	144.697	1982 AHA
(RN/LPN)[a]	3.539	6.953	1982 AHA
(RN/ANP)[a]	2.893	4.077	1982 AHA
RN[b]	116.037	135.924	1982 AHA
LPN[b]	45.893	50.480	1982 AHA
ANP[b]	58.490	70.416	1982 AHA
LPN/RN wage	0.715	0.060	1980 Census
ANP/RN wage	0.519	0.055	1980 Census
Discharges	6730.385	6194.323	1982 AHA
Medicare casemix index	1.027	0.088	1983 HCPA
Length of stay	6.477	1.430	1982 AHA
Outpatient visits	42,484.630	60,651.168	1982 AHA
Occupancy rate	0.683	0.145	1982 AHA
Percent intensive care days	0.054	0.041	1982 AHA
Inpatient surgical operations per discharge	0.367	0.155	1982 AHA
Ambulatory surgical operations per outpatient visit	0.021	0.037	1982 AHA
Births per discharge	0.088	0.064	1982 AHA
Interns/residents per bed	0.021	0.075	1983 HCFA
Government hospital	0.292	M-w-	1982 AHA
Por-profit hospital	0.093	_-_-	1982 AHA
Rural hospital	0.481	----	1982 AHA
Herfindahl	0.164	0.140	1982 AHA
N	1402	1402	----

Note: RN = registered nurse, LPN = licensed practical nurse, ANP = ancillary nursing *personnel.*, 1982 AHA = 1902 American Hospital Association Annual Survey of Hospitals, 1980 Census = special tabulation of 1980 Census of Population and Housing data, HCFA = Health Care Financing Adminstration.

[a]Includes full-time equivalent employees and budgeted vacancies.

[b]Includes full-time equivalent employees and contract personnel.

TABLE 3

ESTIMATES OF HOSPITAL DEMAND FOR REGISTERED NURSES AND NURSING PERSONNEL MIX

Variable	DEPENDENT VARIABLE RN[a,c]	(RN/LPN)[a,c]	(RN/ANP)[a,c]	RN[b,c]
Constant	-5.061* (0.156)	1.107* (0.378)	1.362* (0.409)	-6.449* (0.189)
LPN/RN wage[c]	0.229* (0.113)	1.836* (0.274)	-----	-----
ANP/RN wage[c]	0.600* (0.088)	-----	1.304* (0.218)	-----
LPN[b,c]	-----	-----	-----	-0.124* (0.013)
ANP[b,c]	-i--r	-----	-----	-0.045* (0.012)
Discharges[c]	0.864* (0.017)	-0.093 (0.043)	-0.090* (0.045)	0.965* (0.025)
Medicare casemix[c]	0.688* (0.124)	0.834* (0.315)	0.820* (0.328)	0.820* (0.130)
Length of stay[c]	0.578* (0.044)	-0.067 (0.112)	-0.280* (0.117)	0.690* (0.048)
Outpatient visits[c]	0.092' (0.013)	0.070* (0.032)	0.076. (0.033)	0.134' (0.013)
Occupancy rate[c]	-0.248* (0.040)	-0.291* (0.101)	-0.239* (0.105)	-.203* (0.042)
Percent intensive care days	2.033* (0.220)	1.691* (0.557)	3.299* (0.578)	1.937* (0.229)
Inpatient surgical operations per discharge	0.569* (0.068)	0.329 (0.172)	1.113* (0.179)	0.629. (0.071)
Ambulatory surgical operations per outpatient visit	0.685* (0.225)	1.869* (0.570)	0.327 (0.590)	0.754* (0.234)
births per discharge	0.799* (0.133)	0.530 (0.337)	0.566 (0.351)	0.834* (0.139)
Interns/residents per bed	0.453* (0.114)	0.449 (0.290)	0.337 (0.302)	0.332* (0.119)
Government hospital	-0.073* (0.019)	-0.104* (0.047)	-0.277* (0.049)	-0.093* (0.020)
Cot-profit hospital	-0.022 (0.020	0.029 (0.070)	0.227* (0.072)	-0.044 (0.029)
Rural hospital	-0.114* (0.021)	-0.242' (0.052)	-0.143* (0.053)	-0.156* (0.020)
Herfindahl	-0.122* (0.055)	-0.534* (0.140)	-0.112 (0.144)	-0.131. (0.057)
R^2	0.948	0.233	0.292	0.944
N	1402	1402	1402	1402

Note: RN = registered nurse, LPN = licensed practical nurse, ANP = ancillary nursing personnel. Standard errors are in parentheses. The * indicates significance at the 5 percent level.

[a]Full-time equivalent employment sad budgeted vacancies.

[b]Full-time equivalent employment and contract personnel.

[c]The natural logarithm of the variable is taken.

TABLE 4

PREDICTED CHANGES IN HOSPITAL REGISTERED NURSE DEMAND, 1982-87[a]

	Change 1982-87	Estimated Effect on RN Demand
Actual RN ataffing change	10.9%[c]	--
Wage Effects		
LPN/RN wage	-8.5[b]	-1.93
ANP/RN wage	-8.2[b]	-4.9
Total	--	-6.8
Output Effects		
Discharges	-20.8[c]	-18.0
Medicare Casemix	13.4[d]	9.2
Length of stay	-10.3[c]	-6.0
Outpatient visits	17.7[e]	1.6
Occupancy rate	-19.6[c]	4.9
Percent intensive care days	1.5[f,g]	3.0
Inpatient surgical operations per discharge	-5.2[c,f]	-3.0
Ambulatory surgical operations per outpatient visit	2.2[c,f]	1.5
Births per discharge	0.8[c,f]	0.6
Total	--	-6.2
Output and wage effects	--	-13.0
Direct Substitution Effects[h]		
LPN	-28.0[c]	3.5
ANP	-34.7[c]	1.6
Total	--	5.1

Note: RN = registered nurse, LPN = licensed practical nurse, ANP = ancillary nursing personnel. The estimated effects are calculated from the Cobb-Douglas demand function regression coefficients reported in Table 3 .

[a]For the sample of 1402 hospitals used for the regressions reported in Table 3.

[b]Estimated from unpublished U.S. Bureau of Labor Statistics data tabulated from the Current Population Survey.

[c]Median of percent changes for regression sample of 1402 hospitals, calculated from 1982 and 1987 American Hospital Association (AHA) Annual Survey of Hospitals tapes.

[d]1981-87 change for all hospitals eligible for Medicare's Prospective Payment Payment system taken from Table 1.

[e]Calculated from outpatient visit figures for all nonfederal short-term general hospitals in Table 1 because of the incomparability of 1982 outpatient visits reported on the AHA survey with other years.

[f]1982-87 change in percentage points.

[g]Estimated for 1982-87 from trends in 1982 and 1985 AM annual survey data. A change in the AHA survey after 1985 makes intensive care days figures incomparable with 8rlier years.

[h]Calculated from the coefficient8 of LPN and ANP in the RN requirements regression reported in Table 3.